Title	New Methods of Dielectric Measurement in the Centimeter Wave Region
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for K/L ratio and 15.0 ± 1.6 for L/M ratio. The values of α_K and K/L ratio were assumed to be in accord with those of the former authors (M. A. Waggoner, *Phys. Rev.* **82**, 906 (1951); A. Mitchel and C. Peacock, *Phys. Rev.* **75**, 197 (1949)), and the value of L/M ratio was presented as a new value.

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2. New Methods of Dielectric Measurement in the Centimeter Wave Region

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In the previous paper (This Bulletin, **31**, 108 (1953)), we have proposed several new methods for dielectric measurement using the wave guide in the centimeter wave region. Our methods contain as special cases both the method by S. Roberts and A. von Hippel and that by W. H. Surber and G. E. Crouch which have so far been well used.

This time, we have derived the explicit expressions of ε^* which are expressed in terms of measured quantities only and very convenient and have ascertained that especially the method based on the following expression is very practical:

$$\varepsilon' = \left[1-\left(\frac{\lambda}{\lambda_c}\right)^2\right] \frac{(K_1-K_2)^2\dfrac{\Gamma_1}{\Gamma_2} - \left(\dfrac{1}{\Gamma_2}-\Gamma_1\right)^2 K_1K_2}{\left[\left(\dfrac{1}{\Gamma_2}-\Gamma_1\right)K_1K_2\right]^2 + \left[(K_1-K_2)\dfrac{\Gamma_1}{\Gamma_2}\right]^2} + \left(\frac{\lambda}{\lambda_c}\right)^2 \quad (1)$$

$$\varepsilon'' = \left[1-\left(\frac{\lambda}{\lambda_c}\right)^2\right] \frac{(K_1-K_2)\left(\dfrac{1}{\Gamma_2}-\Gamma_1\right)\left(K_1K_2+\dfrac{\Gamma_1}{\Gamma_2}\right)}{\left[\left(\dfrac{1}{\Gamma_2}-\Gamma_1\right)K_1K_2\right]^2 + \left[(K_1-K_2)\dfrac{\Gamma_1}{\Gamma_2}\right]^2}. \quad (2)$$

The method is such that we measure Γ_i (VSWR) when we adjust the length l_i of the air column behind the sample with the plunger so that the position x_o of E_{min} measured from the front face of the sample may be $(2n+1)\lambda_g/4$ $(i=1)$ and $n\lambda_g/2$ $(i=2)$ and $K_i \equiv \tan 2\pi\, l_i/\lambda_g$.

Our experiments have been performed on $C_{15}H_{31}CH_2OH$ by using the above three methods with the frequency 9450 Mc/sec ($\lambda = 3.172$ cm), in which the values of the dielectric constant ε' agree in 3 significant figures: $\varepsilon' = 2.31$, and $\tan\delta$ lies within the range of about $(10 \sim 25)\times 10^{-2}$.

These methods can in principle be applied to any ε^*, no matter whether the loss be large or small, but in case of the sample of too small loss, the effect of the loss of the guide wall, the terminating plate and others must be considered. Accordingly, the fundamental equation including these losses has been derived:

$$\left.\begin{aligned}
&\frac{\varepsilon' - \left(\frac{\lambda}{\lambda_c}\right)^2 - j\varepsilon''}{\varepsilon_g' - \left(\frac{\lambda}{\lambda_c}\right)^2 - j\varepsilon_g''} = \frac{(T_2 - T_1) + (X_1' - X_2')}{(T_2 - T_1)X_1'X_2' + (X_1' - X_2')T_1T_2} \\
&T_i \equiv \frac{\Gamma_i + j\cot\frac{2\pi}{\lambda_g}x_{oi}}{1 + j\Gamma_i\cot\frac{2\pi}{\lambda_g}x_{oi}} \\
&X_i'(l_i) \equiv \frac{X + \tanh\gamma_g l_i}{X\tanh\gamma_g l_i + 1} \\
&\varepsilon_g' - j\varepsilon_g'' \equiv \left(\frac{\lambda}{2\pi}\right)^2\left[a_g - \left(\frac{2\pi}{\lambda_g}\right)^2\right] + \left(\frac{\lambda}{\lambda_c}\right)^2 - j\frac{\alpha_g}{\pi\lambda_g}\lambda^2 ,
\end{aligned}\right\} \quad (3)$$

where λ_g denotes the resultant attenuation by the wall loss, the slot, the air loss and the junction loss, and X the loss of the terminating plate.

By use of this equation, the effect of the loss of the terminating plate on the sample length and the electrical position of the terminating plate is discussed.

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3. New Approximate Methods of Dielectric Measurement in the Centimeter Wave Region

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Many dielectric measurements using the wave guide in the centimeter wave region have been based on the approximation of the complicated implicit expression containing ε^*. T. W. Dakin and C. N. Works have given electromagnetic-theoretically the approximate form of the method by S. Roberts and A. von Hippel, and circuit-theoretically W. H. Surber and G. E. Crouch the approximate method which needs the continuous deformation of the sample.

The authors have derived both electromagnetic-theoretically and circuit-theoretically the fundamental equation which is very practical for dielectric measurement of low loss material as the approximation of the fundamental equation of methods given in the previous paper (This Bulletin, **31**, 108 (1953)):

$$\frac{\beta_a}{\beta_g}\left[(\coth\alpha_a D - \tanh\alpha_a D)\cos^2\left(\beta_a D + \tan^{-1}\frac{\beta_a K}{\beta_g}\right) + \tanh\alpha_a D\right]$$

$$= \left(\Gamma - \frac{1}{\Gamma}\right)\cos^2\frac{2\pi}{\lambda_g}x_0 + \frac{1}{\Gamma}(\equiv S) \quad \alpha_a \ll \beta_a , \qquad (1)$$

from which many methods follow.

In these methods Γ (VSWR) and x_0 (the position of E_{min} measured from the